Fundamental Astronomy

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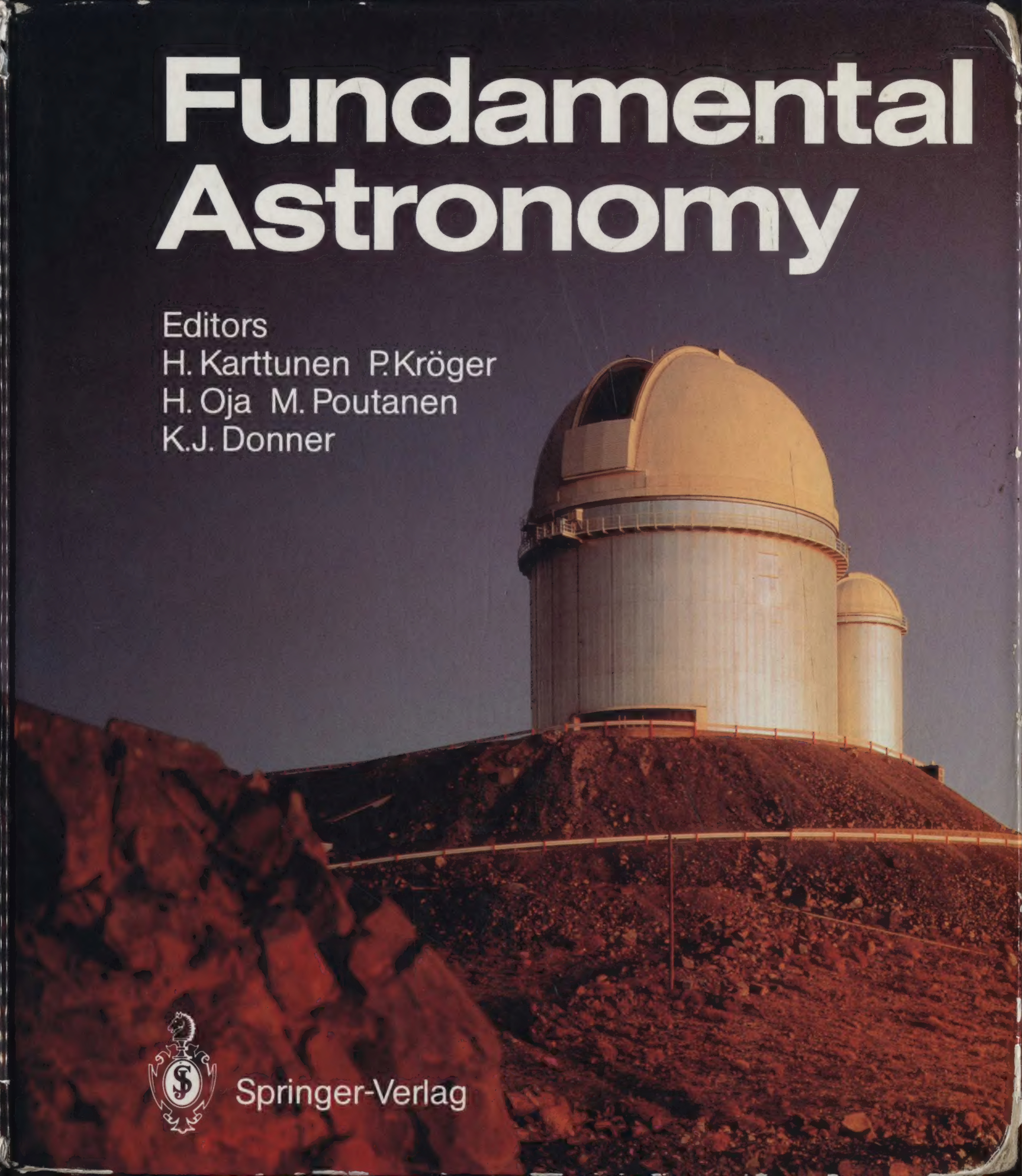

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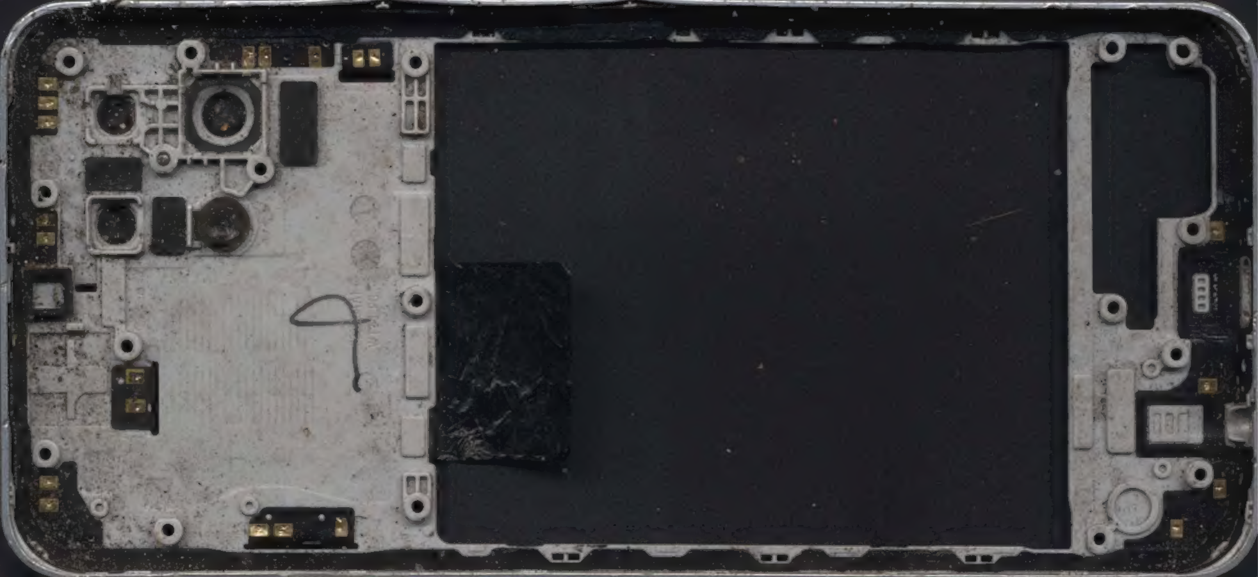
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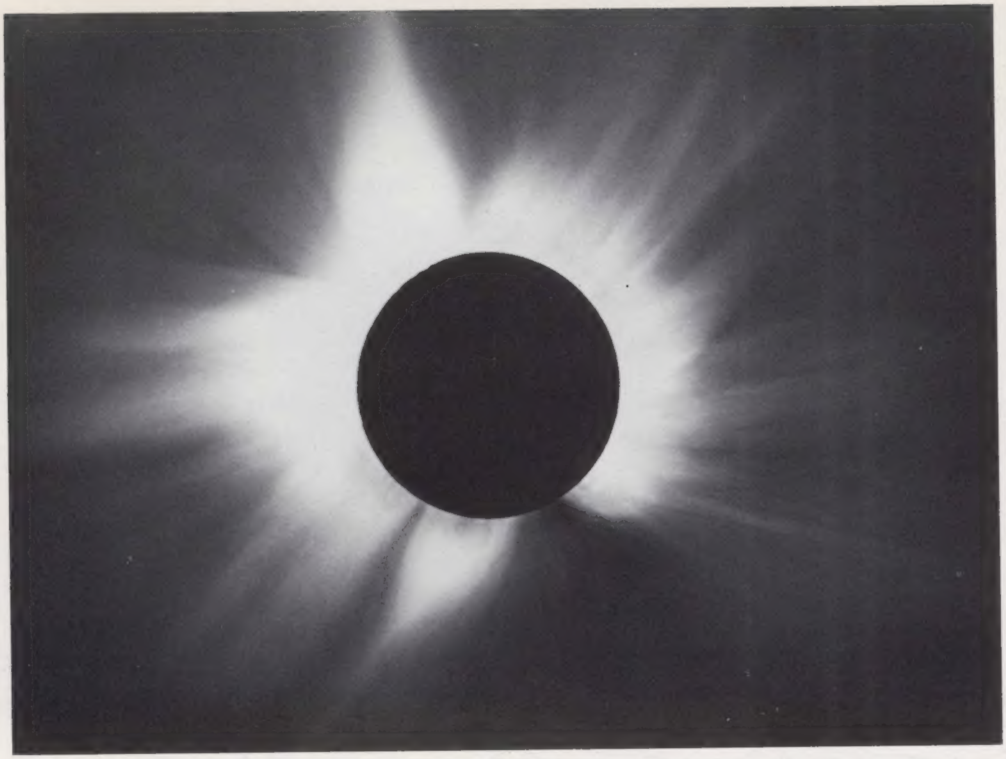


Fig. 13.8. Previously, the corona could be studied only during total solar eclipses. The picture is from the eclipse 7.3.1970. Nowadays the corona can be studied continuously using the so-called coronograph

13.3 Solar Activity

Sunspots. The clearest visible sign of solar activity are the *sunspots*. The existence of sunspots has been known for long (Fig. 13.9), since the largest ones can be seen with the naked eye by looking at the Sun through a suitably dense layer of fog. More precise observations became available beginning in the 17th century, when Galilei started to use the telescope for astronomical observations.

A sunspot looks like a ragged hole in the solar surface. In the interior of the spot is a dark *umbra* and around it, a less dark *penumbra*. By looking at spots near the edge of the solar disc, it can be seen that the spots are slightly depressed with respect to the rest of the surface. The surface temperature in a sunspot is about 1500 K below that of its surroundings, which explains the dark colour of the spots.

The diameter of a typical sunspot is about 10000 km and its lifetime is from a few days to several months, depending on its size. The larger spots are more likely to be long-lived. Sunspots often occur in pairs or in larger groups. By following the motions of the spots, the period of rotation of the Sun can be determined.

The variations in the number of sunspots have been followed for almost 250 years. The frequency of spots is described by the Zürich sunspot number Z:

$$Z = C(S + 10G) , \tag{13.1}$$

where S is number of spots and G, the number of spot groups visible at a particular time. C is a constant depending on the observer and the conditions of observation.

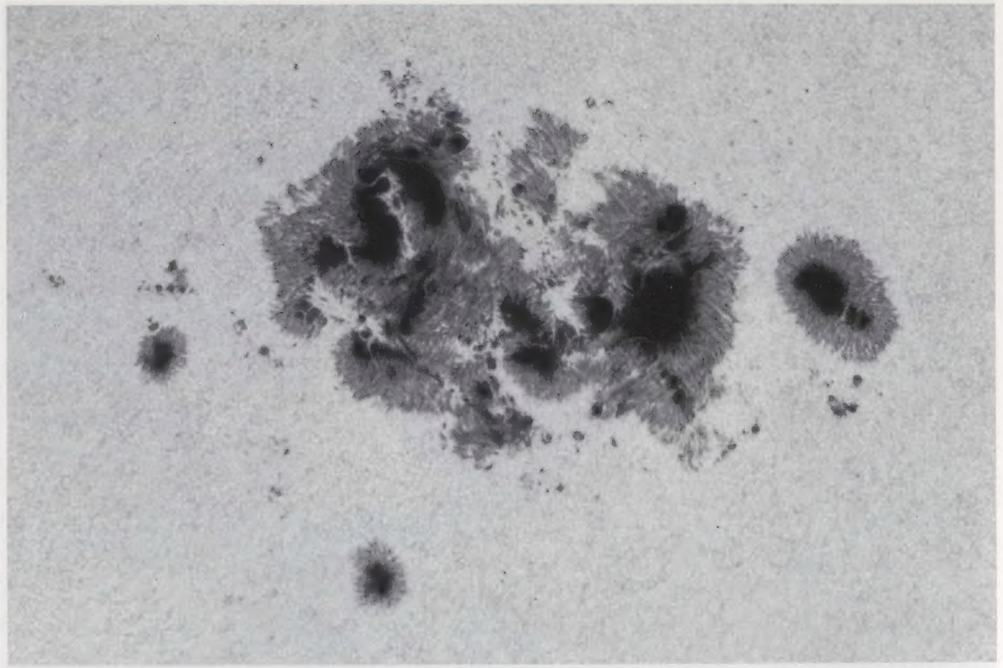


Fig. 13.9. The sunspots are the form of solar activity that has been known for the longest time. (Photograph Mt. Wilson Observatory)

In Fig. 13.10, the variations in the Zürich sunspot number between the 18th century and the present are shown. Evidently the number of spots varies with an average period of about 11 years. The actual period may be between 7 and 17 years. In the past decades, it has been about 10.5 years. Usually the activity rises to its maximum in about 3 – 4 years, and then falls off slightly more slowly. The period was first noted by *Samuel Heinrich Schwabe* in 1843.

The variations in the number of sunspots have been fairly regular since the beginning of the 18th century. However, in the 17th century, there were long intervals when there were essentially no spots at all. This quiescent period is called the *Maunder minimum*. The similar *Spörer minimum* occurred in the 15th century, and other quiet intervals have been inferred at earlier epochs. The mechanism behind these irregular variations in solar activity is not yet understood.

Magnetic Phenomena Related to Sunspots. The magnetic fields in sunspots are measured on the basis of the Zeeman effect, and may be as large as 0.45 tesla. (The Earth's magnetic field is 0.06 mT.) The strong magnetic field inhibits convective energy

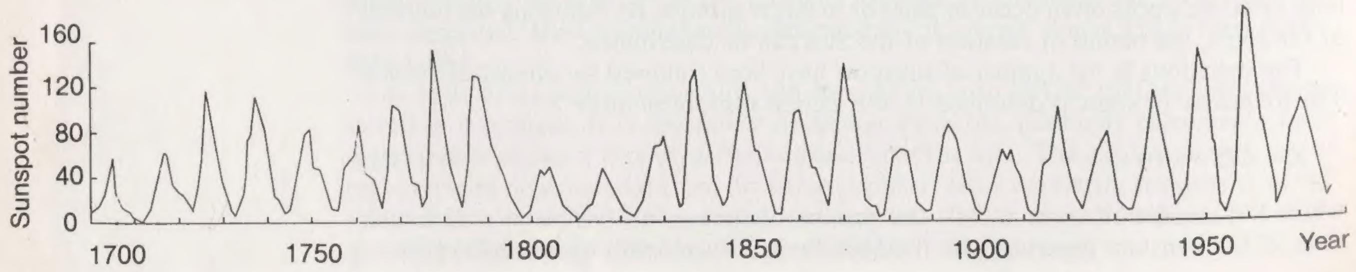


Fig. 13.10. The Zürich sunspot number from 1700 to 1977. The number of sunspots and spot groups varies with a period of about 11 years

transport, which explains the lower temperature of the spots. The periodic variation in the number of spots reflects a corresponding variation in the magnetic field.

A conducting medium, such as the outer layers of the Sun, cannot move across the magnetic field lines. The field is frozen into the plasma and is carried along by it. The rotation period of the Sun is 25 days near the equator and more than 30 days at the poles. This differential rotation will distort the mean magnetic field.

The solar surface is filled with magnetic flux tubes, where the field strength is 0.1 – 0.2 T. Their total effect is to produce a weak, almost dipolar, global magnetic field. The differential rotation winds this mean field into an ever tighter spiral around the Sun (Fig. 13.11). In a few years, the field lines become essentially rings the equatorial direction. These will then be raised and twisted by rising, rotating convective currents. As an end result, the dipole field is re-formed, but with a direction opposite to the orignal one. On average, one such cycle takes 11 years. The total magnetic cycle is therefore 22 years, after which the field returns to its original form and polarity.

Sunspots often occur in pairs where the fields of the components have opposite polarities. This can be understood if the magnetic field in the spot pairs rises into a loop above the solar surface (Fig. 13.12). When gas is streaming along such a loop from one spot to the other, it becomes visible as a *loop prominence.*

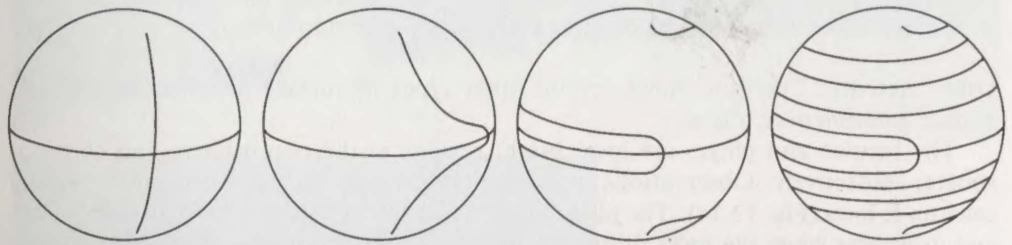


Fig. 13.11. Because the Sun rotates faster at the equator than at the poles, the field lines of the solar magnetic field are drawn out into a tight spiral

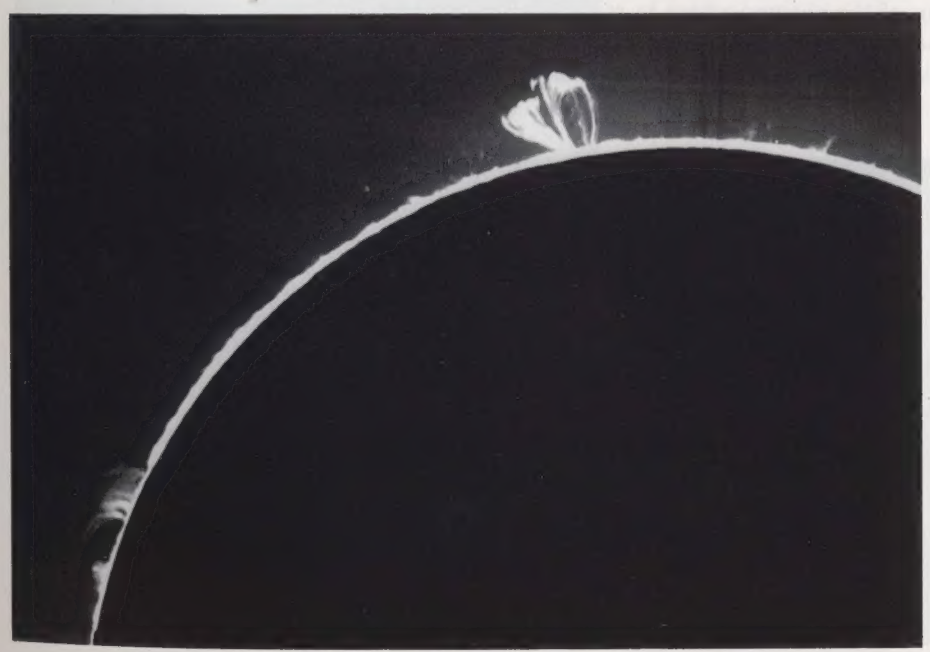
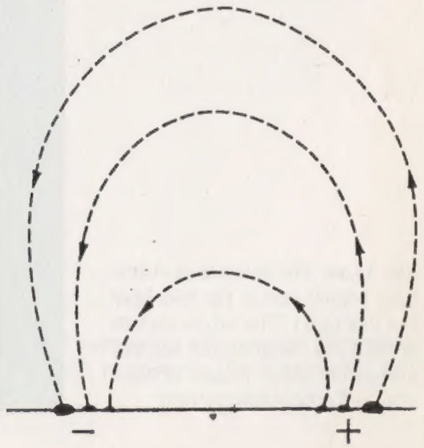
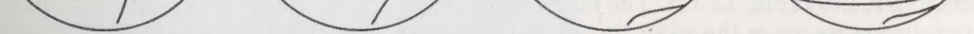


Fig. 13.12. In pairs of sunspots, the magnetic field lines form a loop outside the solar surface. Material streaming along the field lines may form loop prominences. (Photograph Mt. Wilson Observatory)





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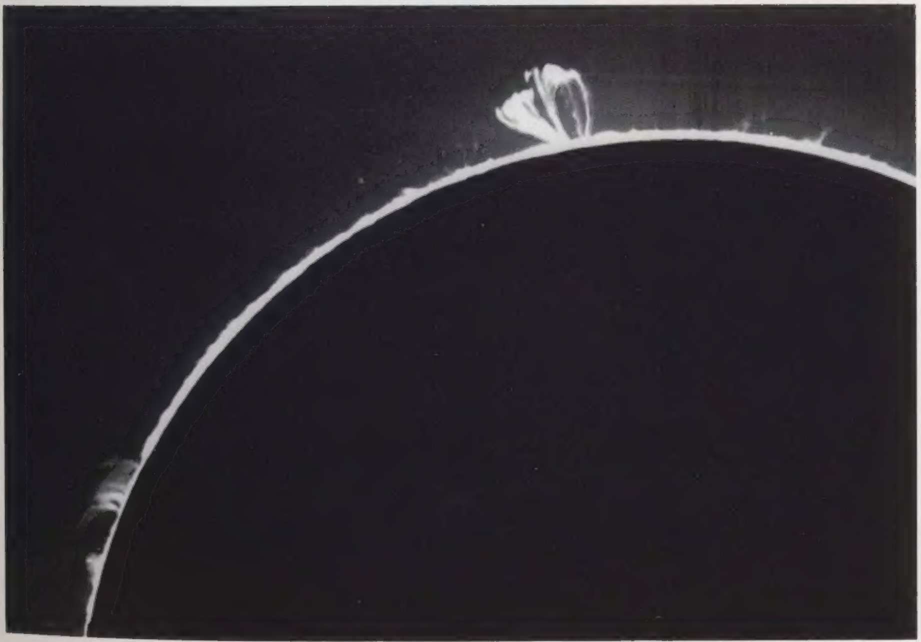

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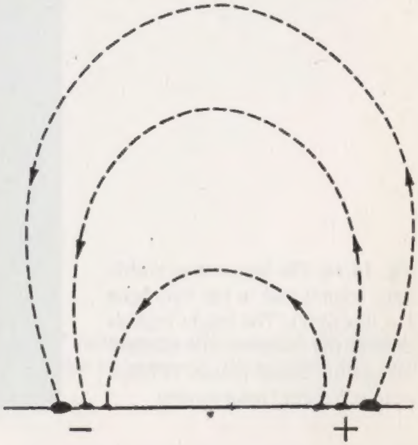

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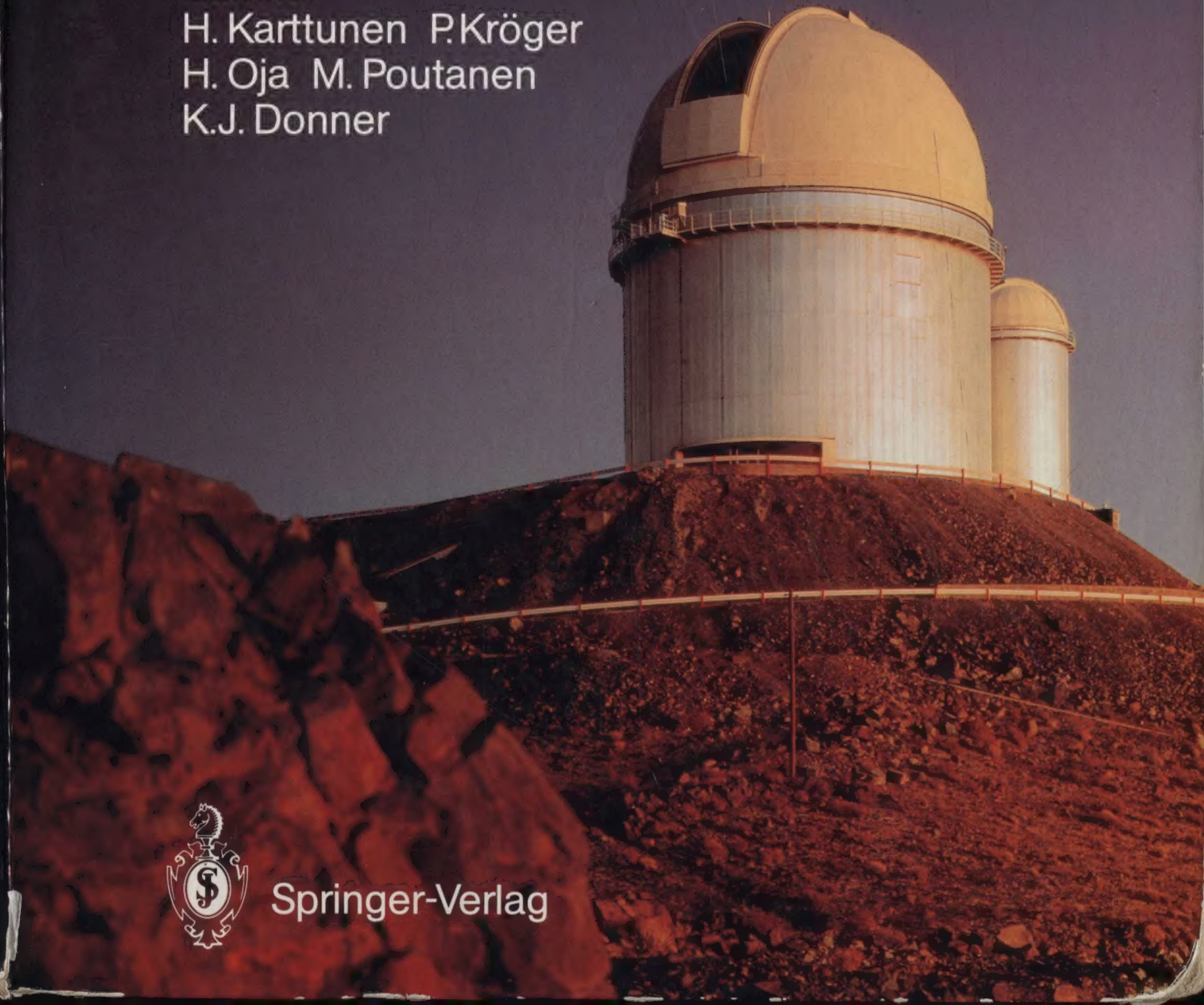

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Fundamental Astronomy provides a well-balanced and comprehensive introduction to the various fields of classical and modern astronomy. Emphasizing the astronomical concepts and the underlying physical principles at the same time, the text provides a sound basis for more advanced studies in the astronomical sciences.

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